DESIGN FORMULATION OF FRESHWATER FISH FEED FROM PALM KERNEL CAKE (PKC)

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ABSTRACT

This study is about design formulation of freshwater fish feed from palm kernel cake (PKC). The objectives in this study are to study the nutrition composition of PKC based feed for freshwater fish, to evaluate the palm kernel cake (PKC) used as a possible substitute for soybean meal, corn meal and in an attempt to reduce the impact of rising costs to feed freshwater fish and to determine the appropriate percentage of PKC, and other raw materials for the formulation of feed. There are 3 sample of fish feed (100 gram for each sample) are prepared where the different between of each sample is only the variety percentage of PKC and soybean used. Composition of palm kernel cake (PKC) and final design feed are analyzed by using Near-Infrared Analyzer (NIR). Based on the result, the percentage of protein, fiber and fat from palm kernel cake (PKC) is moderate and acceptable which is suitable used as ingredient in fish feed and the nutrient composition inside the all designed feed is similar or within the range to the standard pellet feed. The sample 2 is the preferable formulation as it used the maximum amount of PKC (30%) and minimum soybean and it can cut off the costing of fish feed.

ABSTRAK

Kajian ini adalah mengenai formulasi makanan ikan air tawar daripada hampas isirung sawit (PKC). Kajian ini bertujuan untuk mengkaji kandungan nutrien dalam PKC sebagai bahan asas dalam makanan ikan, mengkaji penggunaan PKC sebagai pengganti kacang soya dan jagung bagi mengurangkan kesan kenaikan harga makanan ikan air tawar dan untuk menentukan peratus bersesuaian bagi PKC dan bahan asas yang lain dalam formulasi makanan ikan ini. Tiga sampel makanan ikan dengan jisim setiap sampel adalah 100 gram telah diformulasikan dan beza diantara ketiga-tiga sampel ini adalah peratus PKC dan kacang soya yang digunakan. Kandungan nutrien bagi PKC dan makanan ikan telah dianalisa dengan menggunakan alat Near-Infrared Analyzer (NIR). Berdasarkan kepada keputusan yang diperolehi, peratus protein, serat dan lemak daripada hampas isirung sawit (PKC) adalah sesuai dan boleh diterima sebagai bahan dalam penghasilan makanan ikan dan kandungan nutrien dalam ketiga-tiga sampel yang dikaji adalah sama dan meghampiri kandungan nutrient dalam makanan ikan komersial yang terdapat dipasaran. Sampel B adalah formulasi terbaik kerana ia menggunakan kuantiti hampas isirung kelapa sawit yang maksimum iaitu sebanyak 30 peratus dan kuantiti kacang soya yang sedikit serta ia mampu untuk megurangkan kos penghasilan makanan ikan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PKC	-Palm kernel cake
EFB	-Empty fruit bunches
MARDI	-Malaysia Agriculture and Development Institute
DO	-Dissolve oxygen
PKE	-Palm Kernel Expeller
MTA	-Metric tons per annum
MPOB	-Malaysian Palm Oil Board
TDN	-Total digestible nutrient
EFA	-Essential fatty acid
NIR	-Near-infrared analyzer
FKKSA	-Fakulti Kejuruteraan Kimia & Sumber Asli
DM	-Dry matter
NDF	-Neutral Detergent Fibre
ADF	-Acid Detergent Fibre
CF	-Crude fibre
CP	-Crude protein
EE	-Crude fat

LIST OF SYMBOLS

%	-Percent
$^{\circ}C$	-Degree Celcius
&	-and
CO_2	-Carbon dioxide
kg	-Kilogram
g	-Gram
sp.	-Species
mL	-Milliliter
RM	-Ringgit Malaysia
MJ/kg	-Mega joule per kilogram
NH_3	-Ammonia
ppm	-Part per million
kcal	-Kilocalorie
pH	-Potential for hydrogen ion concentration
mg/kg	-Milligram per kilogram
<	-Less than

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The oil palm tree (*Elaeis guineensis jacq.*) originates from West Africa where it grows in the wild and later was developed into an agricultural crop. It was introduced to Malaysia, then Malaya, by the British in early 1870's as an ornamental plant. In 1917, the first commercial planting took place in Tennamaran Estate in Selangor, laying the foundations for the vast oil palm plantations and the palm oil industry in Malaysia. The cultivation of oil palm increased at a fast pace in early 1960s under the government's agricultural diversification programmers, which was introduced to reduce the country's economic dependence on rubber and tin. Later in the 1960s, the government introduced land settlement schemes for planting oil palm as a means to eradicate poverty for the landless farmers and smallholders. The oil palm plantations in Malaysia are largely based on the estate management system and smallholder scheme.

Today, 4.49 million hectares of land in Malaysia is under oil palm cultivation; producing 17.73 million tonnes of palm oil and 2.13 tonnes of palm kernel oil. Malaysia is one the largest producers and exporters of palm oil in the

world, accounting for 11% of the world's oils & fats production and 27% of export trade of oils & fats. The industry provides employment to more than half a million people and livelihood to an estimated one million people.
(Mohd. Basri Wahid, 2004).

Palm oil is an excellent product and useful product. Although oil from the palm tree is an excellent product for the country, residues from oil palm have not been used sufficiently. Until recently, the remaining 90% empty fruit bunches (EFB), fibers, fronds, trunks, kernels, palm oil mill effluent was discarded as waste, and either burned in the open air or left to settle in waste ponds. Although this way, the palm oil processing industry waste contributed significantly to CO_2 and methane emissions.

Arising from the steep enrichment of globalization and metropolitan growth, today oil palm has demonstrated a wide spectrum of implications, almost every part of its plant. With the prices of the crude petroleum and world's demand for oils and fats escalating to an unprecedented height every other day, the amount of biomass produced by an oil palm tree, inclusive of the oil and lingo-cellulosic materials is on an average of 231.5 kg dry weight/year. For each bunch of the fresh palm fruit, approximately 21% of palm oil, 6–7% of palm kernels, 14–15% of palm fibers, 6–7% of palm shells and 23% of empty fruit bunches can be obtained. This has inspired a growing interest in the utilization of oil palm waste as a renewable source of energy or feedstock for a large variety of downstream products. The potentiality is further strengthened and driven by the insight that oil constitutes only 10% of the palm production, while the rest 90% is the biomass. (K.Y.Foo *et al.,* 2009).

The production of aquatic animals, aquaculture, is currently the fastest growing animal production sector in the world. The rapid expansion of the aquaculture industry is most pronounced in Asia, which contributes about 90% of the total global aquaculture production (by weight). This increase in aquaculture production must be supported by a corresponding increase in the production of formulated diets for the cultured aquatic animals. For most aquaculture systems, the cost of feed constitutes 30% to 60% of the operational costs of the farm, with protein being the most expensive dietary component. Even though fish meal continues to be used as a major source of dietary protein in commercial aquafeeds, its escalating cost have stimulated much research into the use of alternative plant protein sources

Among the plant proteins tested, soyabean meal has enjoyed the most commercial success. Tropical countries import a large volume of soyabean meal for use as a source of protein in the production of animal feeds. In recent years, the cost of imported feed ingredients used in commercial aquafeeds in many developing countries in Asia has continued to rise due to increased global demand and fluctuation in foreign currency exchange. The rising costs of imported ingredients such as fish meal, soyabean meal, corn flour and wheat flour greatly cuts into the profit margins of local fish farmers to such an extent that many local aquaculture enterprises are no longer profitable. This is especially true for the culture of lower-value fish species such as catfish, tilapia and carps. There is currently a great interest within the animal feed industry to reduce costs by using locally available feed ingredients. (NG Wing Keong, 2004).

Palm Kernel Cake produced in Malaysia is exported at a low price to Europe for use as cattle feed concentrates in dairy cows. PKC is an established feed ingredient for ruminants, supplying valuable dietary sources of protein, energy and fibre. PKC has also been successfully tested in poultry and swine feeds at low levels of incorporation. The low cost and availability of PKC in many tropical countries where aquaculture is practiced have recently generated much interest in its potential use in fish diets. It was expected to reduce the balance of payment of the country. (Hishamuddin Mohd Aspar, 2001).

The studies is concentrated to evaluate PKC as a possible substitute for soybean meal in an attempt to reduce the impact of rising costs to freshwater fish feed.

1.2 Problem Statement

In recent years, the cost of imported feed ingredients used in commercial aquafeeds in many developing countries in Asia has continued to rise due to increased global demand and fluctuation in foreign currency exchange. The rising costs of imported ingredients such as fish meal, soybean meal, corn flour and wheat flour greatly cuts into the profit margins of local fish farmers to such an extent that many local aquaculture enterprises are no longer profitable. There is currently a great interest within the animal feed industry to reduce costs by using locally available feed ingredients. (NG Wing Keong, 2004).

Moreover, the price of the imported feed ingredients is often subjected to price instability. Inconsistent supply of imported raw materials, it further added that alternative formulation of feed using locally available raw materials is not well developed. There are very little information is currently available on the use of PKC in fish diets but Malaysia Agriculture and Development Institute (MARDI) expressed optimism on the prospects of palm kernel cake (PKC) replacing a certain amount of soybean which now the major ingredients for making fish feed.(Chong Jin Hun, 2004)

1.3 Objective

The proposed research was studied to achieve the following objectives:

1) To study the right nutrition composition of PKC based feed for freshwater fish.
2) To evaluate the PKC used as a possible substitute for soybean meal, corn meal and in an attempt to reduce the impact of rising costs to feed freshwater fish.
3) To determine the appropriate percentage of PKC, and other raw materials for the formulation of feed.

1.4 Scope of Study

The scopes of the study are:

1) To analyze the nutrients contents inside PKC.
2) To workout appropriate amount of other protein-based and fiber-based materials that must be added together with PKC.
3) To determine the nutrients composition of final design feed based on protein, fat, fiber and ash content.
4) To compare the composition of final design feed with the commercial pellet feed.
5) To study the cost comparison between PKC and others..

1.5 Research Contribution

The research contributions of the study are:

1) Provide an alternative for fish diet and reduce the cost of imported feed ingredients.
2) Help the local fish farmers to get more profit margins.
3) It was expected to reduce the balance of payment of the country.
4) Opportunity to make sure the residue from oil palm have used effectively and give the more income to our country.
5) Open new opportunities for export of livestock production and facilitate competitive outsourcing of raw materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Fish consumption in Malaysia has increased dramatically in the past 10 years (Fisheries Dept. 2000). Consumers have become more aware of the benefits of eating fish and of consuming fish of high quality. Freshwater fish was found to be a viable resource to meet the demand in the market. Karim (1990) reported that the Malaysian Fisheries Department is now encouraging and expanding freshwater fish-rearing industry among agriculturists and fishermen to increase their income. Fish farming techniques are improving with the introduction of new techniques in order to have consistent supply of freshwater fish throughout the year. The low cost and availability of PKC have recently generated much interest in its potential use in fish diets. Research into alternative locally available feedstuffs such as palm kernel cake (PKC) in crucial for the continue expansion of the aquaculture industry in Malaysia and in other developing countries. This study will focus on fish diet for the fresh water fish. (K A Abbas *et al.*, 2006).

2.2 Type of Fish

Study is specialized and in an attempt on production of freshwater fish feed for type red hybrid tilapia *(Oreochromis sp.)*, catfish *(Clarias gariepinus)* and patin *(Pangasius Sutchi)*. This fish species are popular freshwater fish used as food in Malaysia (Mohsin & Ambak 1983; Fisheries Dept. 2000).

The growing popularity of tilapia among consumers and the ever increasing need to improve food production. The popularity is due to its market acceptability and for relatively tolerance to a wide range of water temperature, dissolved oxygen (DO), salinity, pH, light intensity and photoperiods.(Jose L.Balcazar *et al*.,2003)

Catfishes are commonly found in freshwaters on all continents except Antarctica, and are especially abundant in the tropics of South America, Africa and Asia. They are the only ostariophysans to have penetrated the sea but they have done so to a limited extent. Catfishes have a characteristic but highly varied morphology which has to some extent restricted their ecological niches but has also provided them with the basic equipment to dominate benthic habitats in many freshwater ecosystems. (Michael N. Bruton, 1996).

Patin *(Pangasius Sutchi)* is a freshwater catfish of great economic importance found in rivers, lakes, and swamps of Thailand and the Malay Peninsula. It is widely cultured in ponds and floating cages. This species prefers the deep dark pools of large rivers and lives on a diet of vegetable matter, worms, various grubs, carrion, small fish and freshwater prawns. (K.A.Abbas *et al.,*2006).

Red Hybrid Tilapia
(Oreochromis sp.)

Catfish
(Clarias gariepinus)

Patin
(Pangasius Sutchi)

2.3 Palm Kernel Cake

Palm kernel cake (PKC), sometimes referred to as palm kernel expeller (PKE), has long been known to be an important ingredient for the formulation of animal feeds. Though it is considered to be excellent for ruminants, PKC is also reported to be suitable for use in feed formulations for swine, poultry and horses. PKC is obtained as a by-product from the extraction of palm kernel oil via the mechanical process.

Two methods are used for the extraction of oil from the crushed kernels. These are the conventional mechanical screw press method that results in the expeller pressed palm kernel cake and the solvent (usually hexane) extraction method that results in the solvent extracted type. The production of PKC involves the grinding of palm kernels followed by screw pressing with or without an intermediary flaking and cooking stages. During the screw pressing stage, the raw palm kernel oil is diverted for clarification and the residual PKC is cooled and stored in a warehouse. A simplified flow chart of the extractions of palm kernel oil is shown in Figure 2.1 (Hishamuddin Mohd Aspar, 2001) and the technology process flow diagram for the production of high feed quality PKC is illustrated in Figure 2. (Rohaya Mohamed Halim *et al*., 2005)

Though solvent extraction is also used in the extraction of palm kernel oil but the process is costly and screw press extraction (expeller) is the rule in many palm oil processing plants. The main difference between the solvent extracted PKC and the expeller pressed type is in the ether extract or oil content. The oil content of the former is low, around 0.5 to 3 percent, while that in the latter is higher and ranges between 5 to 12 percent, depending on the extent of oil extraction. No difference can be found in the crude protein contents between the two types, which range from 14.6 to 16.0 percent on dry matter basis.

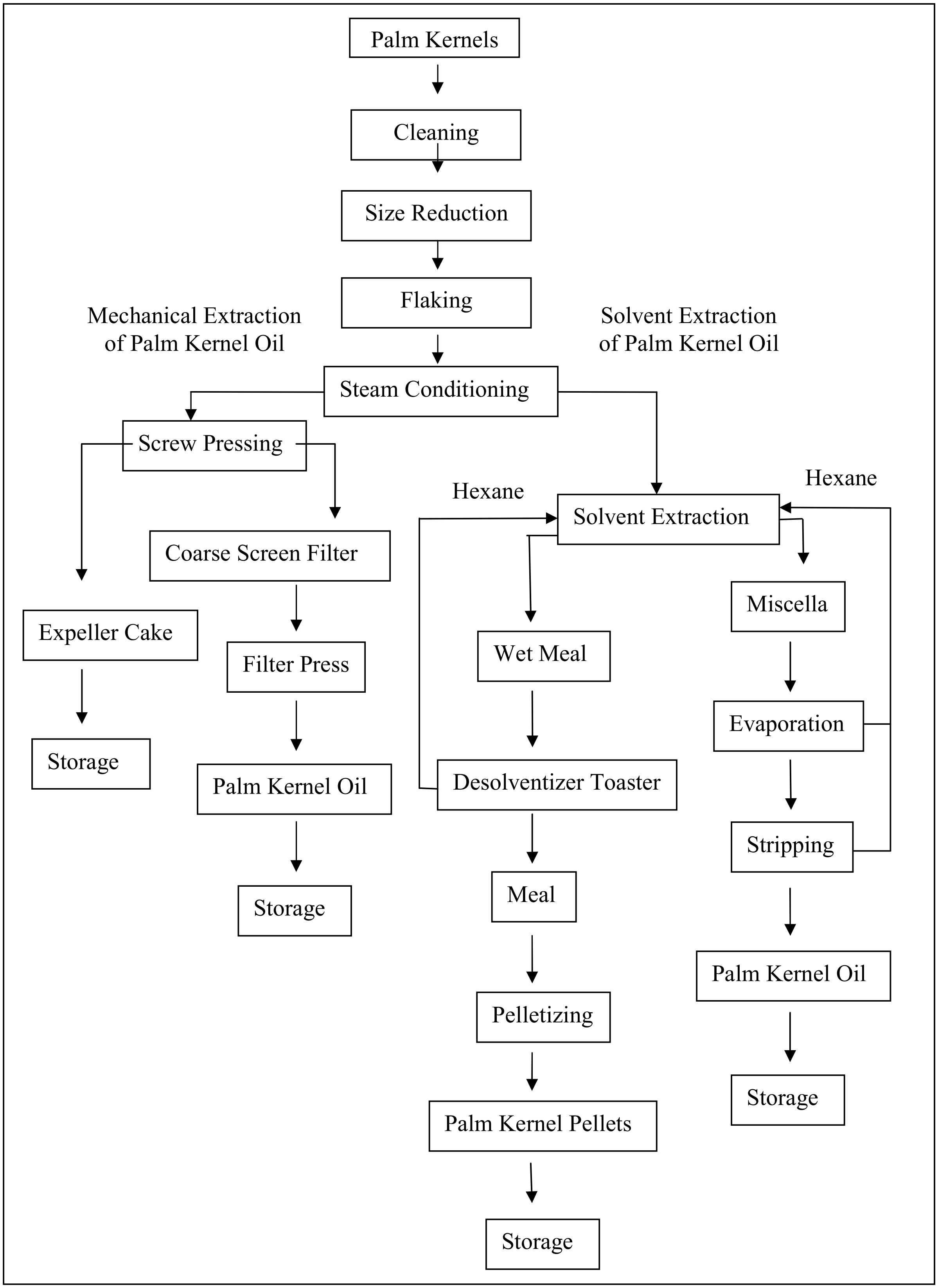

Figure 2.1. The extractions of palm kernel oil.

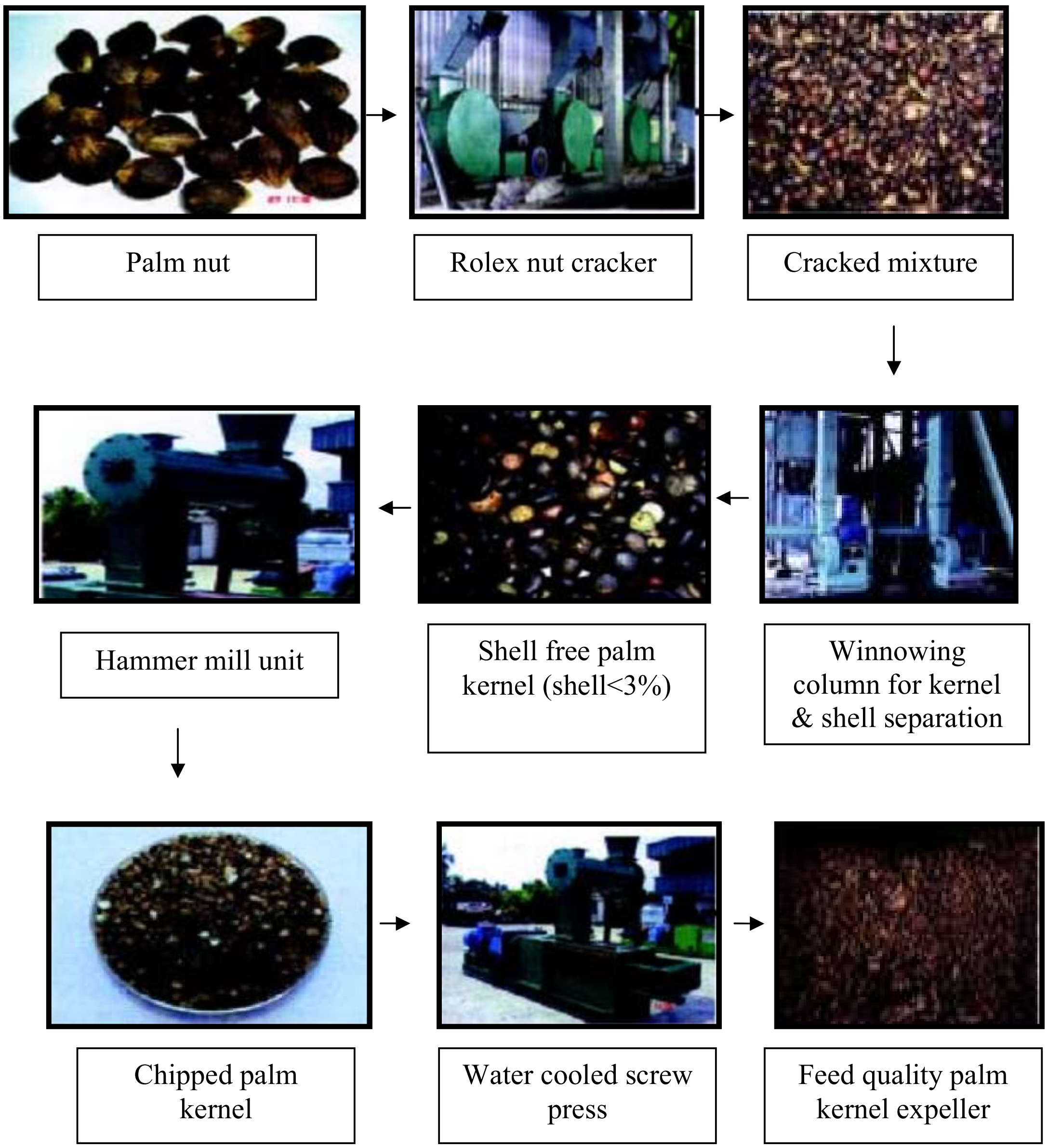

Figure 2.2 The technology and process flow diagram for the production of high feed quality PKC.

Palm kernel cake (PKC) is an important palm kernel oil by-product. In addition to palm oil, Malaysia is also the world's largest producer and exporter of PKC/E and palm kernel oil. In 2005, Malaysia produced about 1.84 million tonnes of crude palm kernel oil and 2.10 million of PKC. Table 2.1 shows the annual production of crude palm kernel oil and PKC in Malaysia

Year	Crude Palm Kernel Oil (MTA)	PKC (MTA)
1996	1,107,045	1,383,034
1997	1,164,697	1,435,104
1998	1,110,745	1,345,277
1999	1,338,905	1,624,134
2000	1,384,685	1,639,227
2001	1,531,917	1,781,641
2002	1,472,932	1,714,522
2003	1,644,126	1,910,100
2004	1,644,445	1,894,017
2005	1,842,628	2,095,876
2006s	1,912,813	2,158,892

Table 2.1 Annual Productions of Crude Palm Kernel Oil and PKC in Malaysia.
Source: Malaysian Palm Oil Board, MPOB (2006)

Although PKC supplies both protein and energy, it is looked upon more as a source of protein. PKC by itself is a medium grade protein feed and with its high fibre content it is often consider as suitable for feeding of ruminants. PKC was ranked a little higher than copra cake but lower than fish meal and groundnut cake especially in its protein value (Devendra, 1977). The nutrient composition of PKC is presented in Table 2.2. (Mustaffa *et al*., 1987)

Nutrient Composition	Solvent extracted			Expeller pressed		
	1	2	3	1	2	3
Dry matter (%)	89.0	91.0	91.0	92.7	93.0	89.1
Crude protein (%)	15.3	15.2	15.0	14.6	14.8	16.0
Crude fibre (%)	14.3	16.0	15.6	12.1	15.7	16.8
Acid detergent fibre (%)	46.1	46.0	40.0	41.8	44.0	39.6
Neutral detergent fibre (%)	66.7	-	-	66.4	-	-
Ether extract (%)	2.9	1.8	0.9	9.1	9.8	10.6
Ash (%)	4.1	3.8	3.5	4.3	4.2	4.1
Nitrogen free extract (%)	63.4	63.2	65.0	59.9	55.5	52.5
Total digestible nutrient, TDN (calculated, %)	75.0	70.0	75.0	72.0	67.0	70.0
Metabolisable energy (cattle, MJ/kg)	13.1	12.2	13.1	12.5	11.7	12.2
Calcium (%)	0.20	0.25	-	0.21	0.20	-
Phosphorus (%)	0.54	0.52	-	0.52	0.32	-
Magnesium (%)	-	0.16	-	-	-	-
Copper (ppm)	34.0	28.5	-	18.0	-	-
Ferrous (mg/kg)	-	4.05	-	-	-	-
Manganese (mg/kg)	-	225.0	-	-	-	-
Zinc (mg/kg)	-	77.0	-	-	-	-

Table 2.2 Nutrient Compositions of Solvent Extracted and Expeller Pressed PKC. Department of Veterinary Services Malaysia, MARDI

Research on the use of PKC in aquaculture feed in Malaysia is very limited Earlier studies indicated that PKC can be tolerated up to 30% in catfish (Clarias gariepinus) and 20% in tilapia (Oreochromis niloticus) rations with no deleterious effects on growth and performance (M Wan Zahari *et al.,* 2001).

2.4 Component of Freshwater Feed

Good nutrition in animal production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species-specific diet formulations supports the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products. Prepared or artificial diets may be either complete or supplemental. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for the optimal growth and health of the fish. Most fish farmers use complete diets, those containing all the required **protein (18-50%)**, **lipid (10-25%)**, **carbohydrate (15-20%)**, **ash (< 8.5%)**, **phosphorus (< 1.5%)**, **water (< 10%)**, and trace amounts of vitamins, and minerals. When fish are reared in high density indoor systems or confined in cages and cannot forage freely on natural feeds, they must be provided a complete diet.

Table 2.3 Product Specification of Commercial Pellet Feed by PRIMAFEED

Product Specification

Feed Code	NUTRITION COMPOSITION OF FEED					
	Size (mm)	Protein (Min.%)	Fat (Min.%)	Fiber (Max.%)	Ash (Max.%)	Moisture (Max.%)
Nursery Diets (micro-pellet):						
PF 1000	1.0	40	3	3	16	10
Grow-out Diets:						
UP 2	2.5 ~ 3.0	32	5	7	13	10
UP 4	4.8 ~ 6.0	28	5	7	13	10

PRIMAFEED is extruded floating feed formulated to meet the nutrient requirements for Catfish / Tilapia / Patin / Milkfish.

2.4.1 Energy

Dietary nutrients are essential for the construction of living tissues. They also are a source of stored energy for fish digestion, absorption, growth, reproduction and the other life processes. The nutritional value of a dietary ingredient is in part dependant on its ability to supply energy. Physiological fuel values are used to calculate and balance available energy values in prepared diets.

To create an optimum diet, the ratio of protein to energy must be determined separately for each fish species. Excess energy relative to protein content in the diet may result in high lipid deposition. Because fish feed to meet their energy requirements, diets with excessive energy levels may result in decreased feed intake and reduced weight gain. Similarly, a diet with inadequate energy content can result in reduced weight gain because the fish cannot eat enough feed to satisfy their energy requirements for growth. Properly formulated prepared feeds have a well-balanced energy to protein ratio.

2.4.2 Protein

Because protein is the most expensive part of fish feed, it is important to accurately determine the protein requirements for each species and size of cultured fish. Proteins are formed by linkages of individual amino acids. Although over 200 amino acids occur in nature, only about 20 amino acids are common. Of these, 10 are essential (indispensable) amino acids that cannot be synthesized by fish. The 10 essential amino acids that must be supplied by the diet are: methionine, arginine, threonine, tryptophan, histidine, isoleucine, lysine, leucine, valine and phenylalanine. Of these, lysine and methionine are often the first limiting amino acids. Fish feeds prepared with plant (soybean meal) protein typically are low in methionine; therefore, extra methionine must be added to soybean-meal based diets in order to promote optimal growth and health. It is important to know and match the protein requirements and the amino acid requirements of each fish species reared.

Protein levels in aquaculture feeds generally average 18-20% for marine shrimp, 28-32% for catfish, 32-38% for tilapia, 38-42% for hybrid striped bass. Protein requirements usually are lower for herbivorous fish (plant eating) and omnivorous fish (plant-animal eaters) than they are for carnivorous (flesh-eating) fish, and are higher for fish reared in high density (recirculating aquaculture) than low density (pond aquaculture) systems.

Protein requirements generally are higher for smaller fish. As fish grow larger, their protein requirements usually decrease. Protein requirements also vary with rearing environment, water temperature and water quality, as well as the genetic composition and feeding rates of the fish. Protein is used for fish growth if adequate levels of fats and carbohydrates are present in the diet. If not, protein may be used for energy and life support rather than growth.

Proteins are composed of carbon (50%), nitrogen (16%), oxygen (21.5%), and hydrogen (6.5%). Fish are capable of using a high protein diet, but as much as 65% of the protein may be lost to the environment. Most nitrogen is excreted as ammonia (NH3) by the gills of fish, and only 10% is lost as solid wastes. Accelerated eutrophication (nutrient enrichment) of surface waters due to excess nitrogen from fish farm effluents is a major water quality concern of fish farmers. Effective feeding and waste management practices are essential to protect downstream water quality.

2.4.3 Lipids (fats)

Lipids (fats) are high-energy nutrients that can be utilized to partially spare (substitute for) protein in aquaculture feeds. Lipids supply about twice the energy as proteins and carbohydrates. Lipids typically comprise about 15% of fish diets, supply essential fatty acids (EFA) and serve as transporters for fat-soluble vitamins. A recent trend in fish feeds is to use higher levels of lipids in the diet. Although increasing dietary lipids can help reduce the high costs of diets by partially sparing protein in the feed, problems such as excessive fat deposition in the liver can decrease the health and market quality of fish.

Simple lipids include fatty acids and triacylglycerols. Fish typically require fatty acids of the omega 3 and 6 (n-3 and n-6) families. Fatty acids can be: a) saturated fatty acids (SFA, no double bonds), b) polyunsaturated fatty acids (PUFA, >2 double bonds), or c) highly unsaturated fatty acids (HUFA; > 4 double bonds). Marine fish oils are naturally high (>30%) in omega 3 HUFA, and are excellent sources of lipids for the manufacture of fish diets. Lipids from these marine oils also can have beneficial effects on human cardiovascular health.

Freshwater fish do not require the long chain HUFA, but often require an 18 carbon n-3 fatty acid, linolenic acid (18:3-n-3), in quantities ranging from 0.5 to 1.5% of dry diet. This fatty acid cannot be produced by freshwater fish and must be supplied in the diet. Many freshwater fish can take this fatty acid, and through enzyme systems elongate (add carbon atoms) to the hydrocarbon chain, and then further desaturate (add double bonds) to this longer hydrocarbon chain. Through these enzyme systems, freshwater fish can manufacture the longer chain n-3 HUFA, EPA and DHA, which are necessary for other metabolic functions and as cellular membrane components. Marine fish typically do not possess these elongations and desaturation enzyme systems, and require long chain n-3 HUFA in their diets. Other fish species, such as tilapia, require fatty acids of the n-6 family, while still others, such as carp or eels, require a combination of n-3 and n-6 fatty acids.